Maize (Zea mays) Biomass and Yield as Influenced by Leguminous and Non-Leguminous Mulch Types in Southwestern Nigeria

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Abstract

Two field experiments were conducted at the Teaching and Research Farm of the Federal University of Technology Akure (7^0 17'N, 15^0 14'E) in the rainforest zone of southwestern Nigeria during the dry and wet seasons of 2013 and 2014 to evaluate the comparative effects of leguminous and non-leguminous mulch types on the growth and yield of maize (*Zea mays* L.). The leguminous plant mulch was *Cajanus cajan* while the non-legume mulch type was *Chromolaena odorata* applied at the rate of 5 t ha^{-1} and NPK 20:10:10 fertilizer was applied at the rate of 200 kg ha^{-1}. The treatment was laid out in randomized complete block design (RCBD) with three replicates. The growth and yield parameters in maize and changes in soil chemical properties were monitored and determined in both experiments. Significant increases in soil organic carbon (SOC), available P, total N, exchangeable bases, maize biomass and yield parameters over the control were obtained for the *Cajanus cajan* mulch treatment applied at 5 t ha^{-1} which were similar to the NPK fertilizer treatment. However, NPK treatment produced the highest grain yields in the dry season while *Cajanus cajan* and NPK treatments produced the highest biomass and grain yields in the wet season.

Keywords: Legumes, non-legumes, mulch, maize, biomass, yield, soil health

Introduction

The physical condition of a soil is one of the fundamental factors affecting crop growth, development and yield. This is because the soil physical properties have very high degree of correlation with crop production and have high influence on soil fertility and crop performance (Nnaji, 2009). However, with the removal of vegetation and subsequently cropping, fertility maintenance becomes a serious problem. The indicators are rapid decline of organic matter and soil nutrients, high soil acidity and erosion which culminate in sharp decline in crop yields. The numerous soil problems are further compounded by the seasonality and erratic distribution of rainfall which results in varying periods of dry spells separated by wet periods (Enwezor *et al.,* 1979). There is, therefore, the need to develop farm management practices that would conserve moisture in the soil to tide crops over during periods of dry spells and protect the soil against erosion during erosive storms. Studies carried out in Nigeria and elsewhere have shown that mulches not only conserved soil moisture and prevented erosion, they also increased soil fauna and flora activities, suppressed weeds and maintained high crop yields (Kurshid *et al.,* 2006; Anikwe *et al.,* 2007; Seyfi and Rashidi, 2007; Essien *et al*., 2009). Different types of materials such as wheat straw, rice straw or husk, plastic film, grass, wood, sand and oil layer have been used as mulches (Khurshid *et al.,* 2006; Seyfi and Rashidi, 2007). Legumes are very important both ecologically and agriculturally because they are responsible for a substantial part of the global flux of N_2 from atmospheric N_2 to fixed form (Patriarca *et al.,* 2002). Also, the low fertility status of most tropical soils hinders maize production as maize has a strong nutrient exhausting effect on the soil. It was observed that maize failed to produce well-filled cobs in plots without adequate nutrients (Adediran and Banjoko, 2003). Mulching with residues of weeds such as siam weed and Mexican sunflower was found to increase yields of crops such as maize (Ojeniyi and Adetoro, 1993; Falade and Ojeniyi, 1997; Awodun and Ojeniyi, 1999) and soil nutrient contents. The mulches have fertilizer effect also (Taiwo and Makinde, 2005). Pigeon peas (*Cajanus cajan*) have been used effectively as a cover crop in coffee, corn, and other crops. Benefits of the pigeon pea cover crop included improved soil fertility, weed competition, and increased arthropod diversity (Odeny, 2007). The roots of pigeon pea excrete organic acids such as citric, piscidic, and tartaric acid, which help to mobilize P in the soil. The leaves that fall from pigeon pea before harvest provide a mulch and can add as much as 90 kg N/ha to the soil that then mineralizes relatively slowly during the subsequent season, releasing N for the next maize crop (Adu-Gyamfi *et al.,* 2007). It was reported that, mulches from pigeon pea residues can be effective for weed suppression (Ekeleme *et al.,* 2003). The use of pigeon peas in multiple cropping systems resulted in greater resource use efficiency, increased crop productivity, more stable or resilient systems over time and less economic risks to small farmers in the tropics (Waddington *et al.,* 2007). It was reported by Chikowo *et al., (*2004) that, pigeon pea develops effective mycorrhizal associations, improving nutrient uptake efficiency, also Shibata and Yano (2003) reported that mycorrhizal associations enhanced the ability of pigeon peas to absorb P ten times faster compared to one time uptake without root inoculation. It was found out that, Siam weed (*Chromolaena odorata*) is widespread throughout the humid forest zone of West Africa and it grows luxuriantly and rejuvenates the soil. Its effectiveness in yam mulching had been reported (Akanbi and Ojeniyi, 2007). Farmers observed that fields colonized by C. *odorata* produced better yields of maize and groundnut. It is, however, obvious that with its abundant biomass production, C. *odorata* contributes significantly to the buildup of organic matter and leads to an increase of the soil pH on very acid soils. *Chromolaena odorata* may enhance the regeneration in heavily disturbed forests that are dominated by grasses. This is due to the improved soil conditions that enhance secondary succession as a result of the presence of this weed. If combined with appropriate tree species, C. *odorata* may be more useful. *Chromolaena odorata* shoot contains 1.26% N, 0.67% P, 1.08% potassium (K), 2.33% Calcium and 0.005% Mg (Olabode *et al*., 2007). *Moringa oleifera* has been reported to improve crop yield by improving soil fertility and providing semi-shade, useful in intercropping systems where intense direct sunlight can damage crops. Also, reducing fallow periods with sown leguminous plants such as *Calopogonium mucunoides* was found to be a technically feasible, low-input method of improving soil nutrient levels for rice cropping in the Guinea and Sudan savannah regions of northern Ghana (Yiridoe *et al.*, 2006) Thus, the objective of this study was to evaluate the comparative effect of leguminous and non-leguminous mulch types on growth and yield component of maize.

Material and Methods

The experiments were conducted at the Teaching and Research Farm of the Federal University of Technology Akure, Ondo State, Nigeria. The area lies within the tropical rainforest belt (7^0 17'N, 15^0 14'E). The rainfall pattern of Akure is bimodal with a wet season of about eight months occurring between April and October and with a brief dry spell which in most cases occur in the second half of August. The peak rainfall periods are June/July and September/October while the short dry season lasts from November to March. The mean daily temperature ranges from 27^0C to 37^0C. The experimental field was mechanically cleared, ploughed and harrowed. The Soil at the experimental site is a clay loam alfisol classified as clayey skeletal oxic-paleustaif, four core samples were collected at random from each treatment plot with the aid of a soil auger at a depth of (0-15cm). The collected core samples were homogenized and a total of twelve composite soil samples were collected from the trial sites for determination of chemical properties before planting and after harvest. The samples were air dried at room temperature, crushed and sieved through a 2mm mesh and subjected to particle size analysis using the Bouyoucos (1951) method. The soil pH was determined by using 1:2 of 10 g of soil to 20 ml distilled water ratio suspension. The suspension was stirred for 30 minutes and determined by glass electrodes pH meters which were standardized with a buffer of pH 7. Total nitrogen in the soil was analysed using Kjeldahl method, while available phosphorus was extracted using Olsen's extract and the P in the extract was determined via the use of spectrophotometer. The organic matter was determined using Walkley-Black (1934) wet Oxidation method. Potassium (K^+), Calcium (Ca^{2+}), Sodium (Na^+), and Magnesium (Mg^{2+}) were extracted by 1M Ammonium acetate (NH_4OAC), at pH 7 and the extracts were determined on a flame photometer while Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by ethylene di-amine tetra acetic acid (EDTA) titration (AOAC, 1997). The site was sectioned out into blocks and plots. Improved hybrid seeds of maize (*Zea mays* L.) was collected from Ondo State Agricultural Development Project Seed Centre in Akure were sown in an already prepared experimental field manually at 3 cm depth. Maize was sown at a spacing of 60 x 30 cm (55,555 plants/ha) with the total number of twenty-eight (28) maize plants per plot. Weed control was done manually by hand pulling and hoeing. The experiments was laid out in a randomized complete block design (RCBD) and lasted for three months with the treatment in three (3) replicates. Each replicate consisted of three (3) treatments. Total land area measured 207 m^2 (23m x 9m) with 9 plots in all and each plot size measured $4m^2$ with 1 m alley ways between plots and replicates. The first experiment was conducted between 2nd of September to 30th November, 2013 while the second experiment was conducted between 1st of May to 30th of July, 2014. Chopped leafy vegetative parts of both leguminous and non-leguminous mulch was applied at 5 t ha^{-1} as treatments across the blocks and plots while NPK 20:10:10 at a recommended rate of 200 kg ha^{-1}. Plant height was measured with a metre rule and number of leaves by direct counting of the leaves. Leaf area was measured with leaf area metre. Dry matter yield was determined using the formulae: Dry matter yield (kg ha^{-1}) = kg stover yield m^{-2} x $10,000m^2$. Shelling percentage, grain yield, biomass yield and harvest index were determined by using standard procedures. The data obtained on the morphological characteristics, yield and yield components were analyzed statistically using the Analysis of Variance. Data were analyzed using SPSS statistical package and the treatment means comparison done with the Duncan's Multiple Range Test (DMRT).

Results and Discussion

Table 1 shows the chemical and physical properties. The pH of the soil was 6.18 and the values of OC, OM, N, P and K in the soil were 1.98 g kg^{-1}, 3.42 g kg^{-1}, 0.48 g kg^{-1}, 3.78 mg kg^{-1} and 0.60 cmol kg^{-1} respectively. The other exchangeable bases such as Na, Ca and Mg were 0.49 cmol kg^{-1}, 2.10 cmol kg^{-1} and 1.50 cmol kg^{-1} respectively. Soil particle fraction showed that the soils are sandy clay loam in texture indicating that the soil is low in organic matter content and high in percentage of sand. The soil was characterized by slight acid with pH value of 6.18. The fertility of the soil was low compared with established critical levels. The organic matter content was a bit high, however the soil was deficient in N and P while K component of the soil was high. The Mg was high while calcium was low. Table 2 shows the effect of leguminous and non-leguminous mulch treatment on soil chemical properties. *Cajanus cajan* mulch treatment applied at 5t/ha improved soil properties by increasing SOC, available P, total N and exchangeable bases after maize harvest while *C.odorata* significantly increased soil pH over other treatments. This increase observed in the *C.odorata* treatment might be due to the effects of the chopped mulch which improved soil potassium and magnesium thereby reducing acidity. Similar results were observed by Egbe et al., 2012 who reported increase in soil pH from *Callandra, Gliricidia* and *Senna* prunnings applied on an andosol in cameroon. Ojeniyi *et al.* (2012) also reported that Mexican sunflower and siam weed respectively reduced soil bulk density, increased total porosity and soil water content. It also increased the soil nutrient levels and subsequently produced high growth of maize. Fallow lands under C. *odorata* produce higher yields of crops such as maize and cassava. This is probably due to the recycling of nutrients and higher litter fall which improves organic matter and soil structure (Torres and Palier, 1989).Table 3 shows the macro-mineral composition of the leguminous and non-leguminous mulch type used in this study. *Cajanus cajan* had the highest content of N (12.44%) of the two mulch materials due to its nitrogen fixing and storage ability while NPK fertilizer had higher N content (18.25%). P content of *Cajanus cajan* (9.86%) was also higher than *Chromolaena odorata* (1.70%) mulch and NPK fertilizer (9.65%), K content (4.12%) was lower than that of NPK fertilizer (9.74%), however it was higher when compared with *Chromolaena odorata* (1.12%). *Chromolaena odorata* had the highest calcium content of the mulch types (3.96mg/kg) and NPK fertilizer (1.87mg/kg). *Cajanus cajan* had the highest composition of Mg (2.90mg/kg) amongst the mulch types while NPK fertilizer recorded the lowest Mg composition (1.21mg/kg). Figures 1 and 2 show the effects of leguminous, non-leguminous mulches and NPK fertilizer on number of leaves per maize plant at two weeks intervals over a period of 9 weeks after treatment application in 2013 and 2014, respectively. In both years, there were no significant differences in the numbers of leaves of maize at 3WAP. Significantly, *Chromolaena odorata* mulch treatment at 5 t ha^{-1} and NPK at 200 kg ha^{-1} had the highest number of leaves in both years. In both years all shrub treatments and NPK fertilizer significantly increased the number of leaves produced when compared with the control at 5, 7 and 9 weeks after treatment application. No significant differences were indicated between *Chromolaena odorata* treatment and NPK fertilizer, but there were variations in the number of leaves in their response to treatments. It was also observed in both years that the number of leaves reduced in 11WAP as a result of shedding of leaves. Significant increases in plant height over the control were obtained for all the treatments throughout the period of growth of maize (Figures 3 and 4). However, NPK fertilizer consistently produced plants with the tallest height while control had the shortest plants in this study. In both years, all the mulches and NPK fertilizer significantly increased maize leaf area throughout the evaluation period when compared with the control (Figure 5 and 6). A comparison of the *Cajanus cajan* mulch treatment and NPK resulted in significantly greater leaf area in the second year. However, NPK at manifested the highest leaf area throughout the evaluation period. Leguminous mulching significantly promoted vegetative growth over the non-leguminous mulch, this may be ascribed to a better soil microclimatic modulation potentials of mulching practice. Steady moisture content and well textured soil probably lead to unrestricted root growth and development which enabled subsequent increase in nutrient absorption. This study corroborated the report of Ba, (1992) who observed that non-mulched plot yielded cucumber with low plant height, branches number, flowers and fruits. Chung, (1987) and Aliudin (1986) also reported that mulches conserved more soil moisture, enhanced vegetative growth and yield contributing characters of garlic. Grass-mulched soil maintained high moisture content to a depth of 60cm and Hatfield et al. (2001) reported a 34-50% reduction in soil water evaporation (Adeoye, 1984), crop residues (grasses, lantana leaves, sorghum, cotton and maize stubbles) as mulches reduces moisture losses and irrigation requirement. There were significant differences in dry matter yields among the treatments in both years. A comparison of the treatments indicated that shrub mulch and NPK fertilizer resulted in significantly greater dry matter yields than the control; NPK gave significantly highest dry matter. The control had significantly lowest dry matter yields in both years (Tables 4 and 5). Significant differences in grain yields were found among the treatments in both years (Tables 4 and 5). Analysis identified two general grouping of the treatments; NPK fertilizer gave the significantly highest grain yield in both years (Tables 4 and 5), except in 2014 when NPK and *Cajanus cajan* had similar yields. The trend in biomass yield as affected by treatments is similar in both years (Tables 4 and 5). The NPK fertilizer significantly increased biomass yield over the mulch treatments and control. The NPK standard gave the significantly highest biomass yield while control gave the lowest yield. Dygima and Demkouma (1986) reported black polyethylene mulch on eggplant and tomato yielding 3.3 times and 2.3 times respectively higher when compared with no mulch since it creates good environment for crops (Thakur et al., 2000). Significant increases in the shelling percentage were noted for the *Chromolaena odorata* mulch treatment and NPK standard over the *Cajanus cajan* and control in both years. However, *Chromolaena odorata* and NPK were not significantly different from *Cajanus cajan* treatment in 2013 (Tables 4 and 5). Significant differences in harvest index were found due to treatment effects in both years (Tables 4 and 5). NPK standard resulted in significantly greater harvest index than the *Cajanus cajan, Chromolaena odorata* mulch treatments and control in the first year while there were no significant differences among NPK, *Cajanus cajan, Chromolaena odorata* mulch treatments in the second year. Control had the lowest harvest index in the second year. The results of this study is corroborated by Muhammad et al. (2009) and Anikwe (2000) who all stated that use of mulch materials either leguminous or non-leguminous as used in this research creates a sound micro ecological environment of the soil, thereby increasing soil moisture content, reducing water infiltration rates, reduces soil sealing, wind and water erosion, weed complexities and the decomposed chopped mulch improves soil aggregation, fertility which leads to a cumulative increase in dry matter and crop yield.

Table 1: *Physico-chemical properties of experimental soil at a depth of (0-15cm) before planting*

Properties	Values
Physical composition (g kg^{-1})	
Sand	52.57
Silt	18.99
Clay	28.44
Textural class	Sandy clay loam
Chemical characteristics	
pH in H_2O (1:1)	6.18
Organic carbon (g kg^{-1})	1.98
Organic matter (g kg^{-1})	3.42
Available P (mg kg^{-1})	3.78
Total N (g kg^{-1})	0.48
Exchangeable bases (cmol kg^{-1})	
Ca	2.10
Mg	1.50
K	0.60
Na	0.49

Table 2: *Physico-chemical properties of top soil (0 –15 cm) of experimental field after harvesting of maize*

Treatments	$pH(H_20)$	OC	P	N	Ca	Mg	K	Na
		(g/kg)	(mg/kg)	(g/kg)	(cmol/kg)			
NPK (20:10:10)	6.12ab	1.74d	3.21b	0.56b	2.50b	1.40b	0.72c	0.24c
Cajanus cajan	5.74b	2.10a	5.23a	0.88a	3.10a	1.90a	0.86b	0.32b
C. odorata	6.62a	1.96bc	3.92ab	0.62b	2.20bcd	1.20bc	0.60d	0.29bc
Control	6.12ab	1.68d	2.12c	0.48bc	2.10bcd	1.40b	0.97b	0.35b

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Duncan's Multiple Range Test.

Table 3: *Chemical composition of shrub mulch and 20:10:10 NPK fertilizer*

Elements	**NPK**	***Cajanus cajan***	***Chromolaena odorata***
N (%)	18.25	12.44	4.22
P (%)	9.65	9.86	1.70
K (%)	9.74	4.12	1.12
Ca (mg/kg)	1.87	3.82	3.96
Mg (mg/kg)	1.21	2.90	1.60

*n = 4

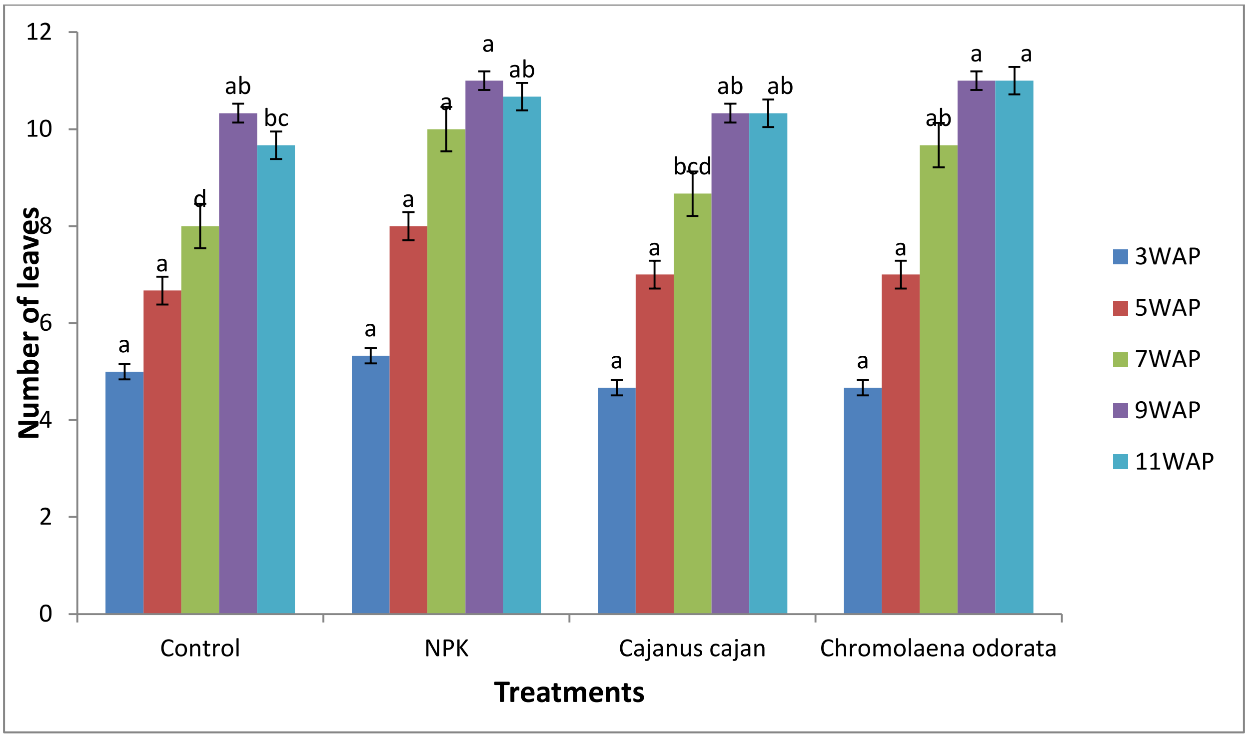

Figure 1: *The effects of mulches and NPK on the number of leaves at different stages of growth of maize in 2013*

Legend: *WAP: Weeks after planting*

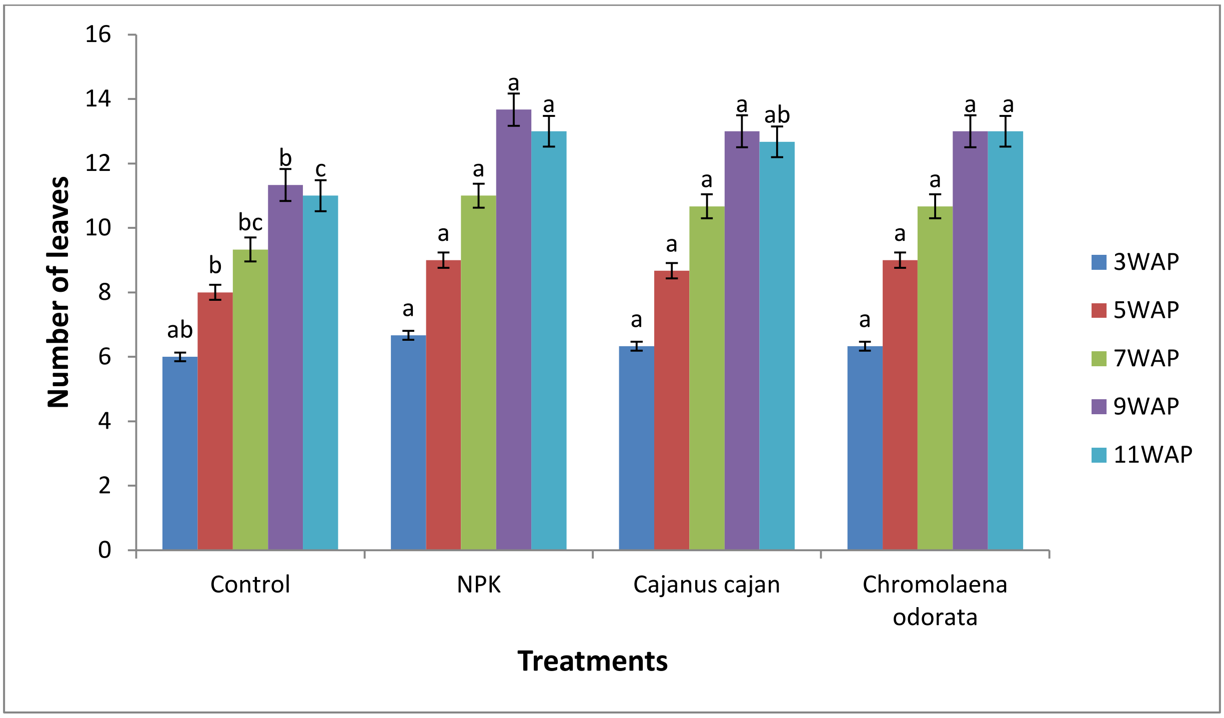

Figure 2: *The effects of mulches and NPK on the number of leaves at different stages of growth of maize in 2014*

Legend: WAP: Weeks after planting

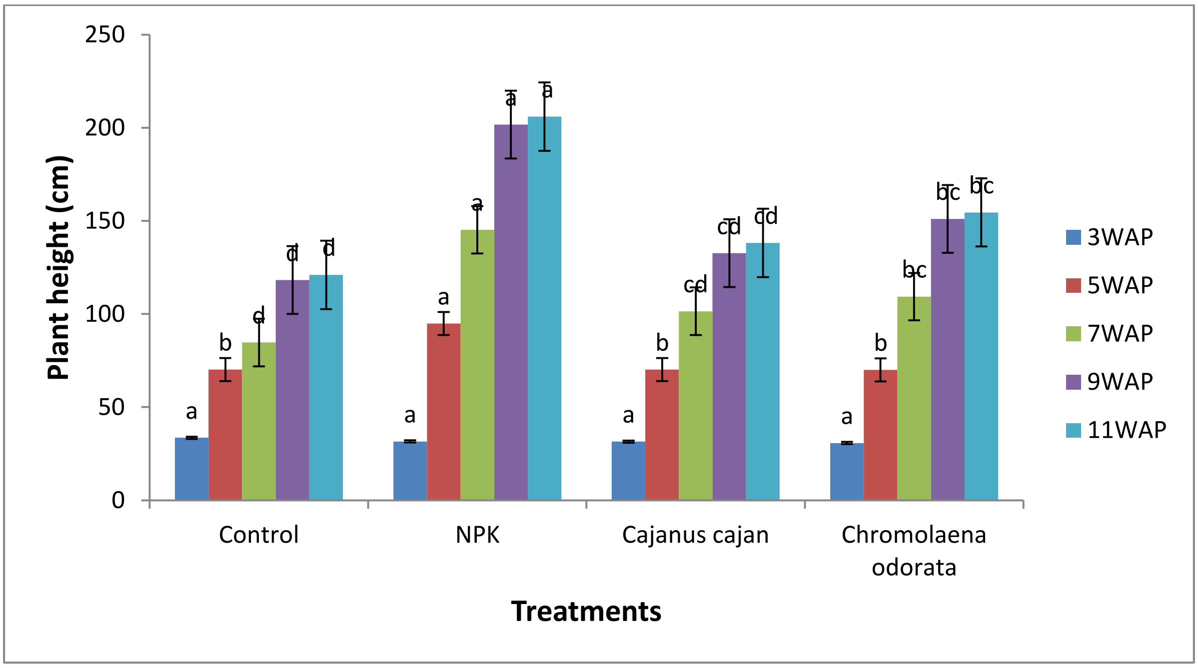

Figure 3: *The effects of mulches and NPK on plant height (cm) at different stages of growth of maize in 2013*

Legend: WAP: Weeks after planting

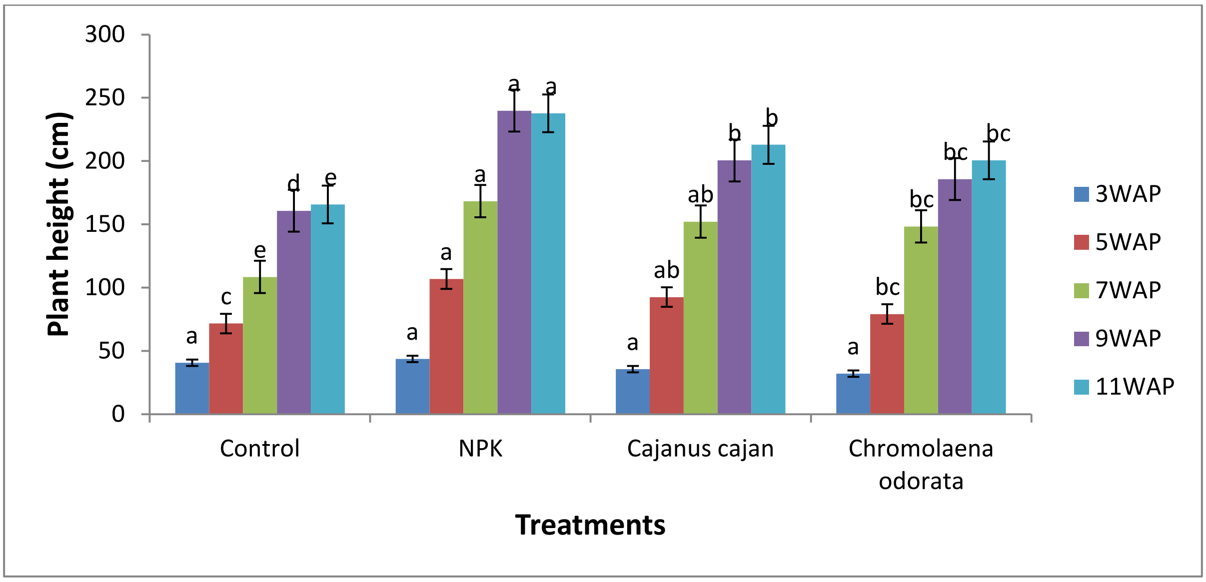

Figure 4: *The effects of mulches and NPK on plant height (cm) at different stages of growth of maize in 2014*

Legend: WAP: Weeks after planting

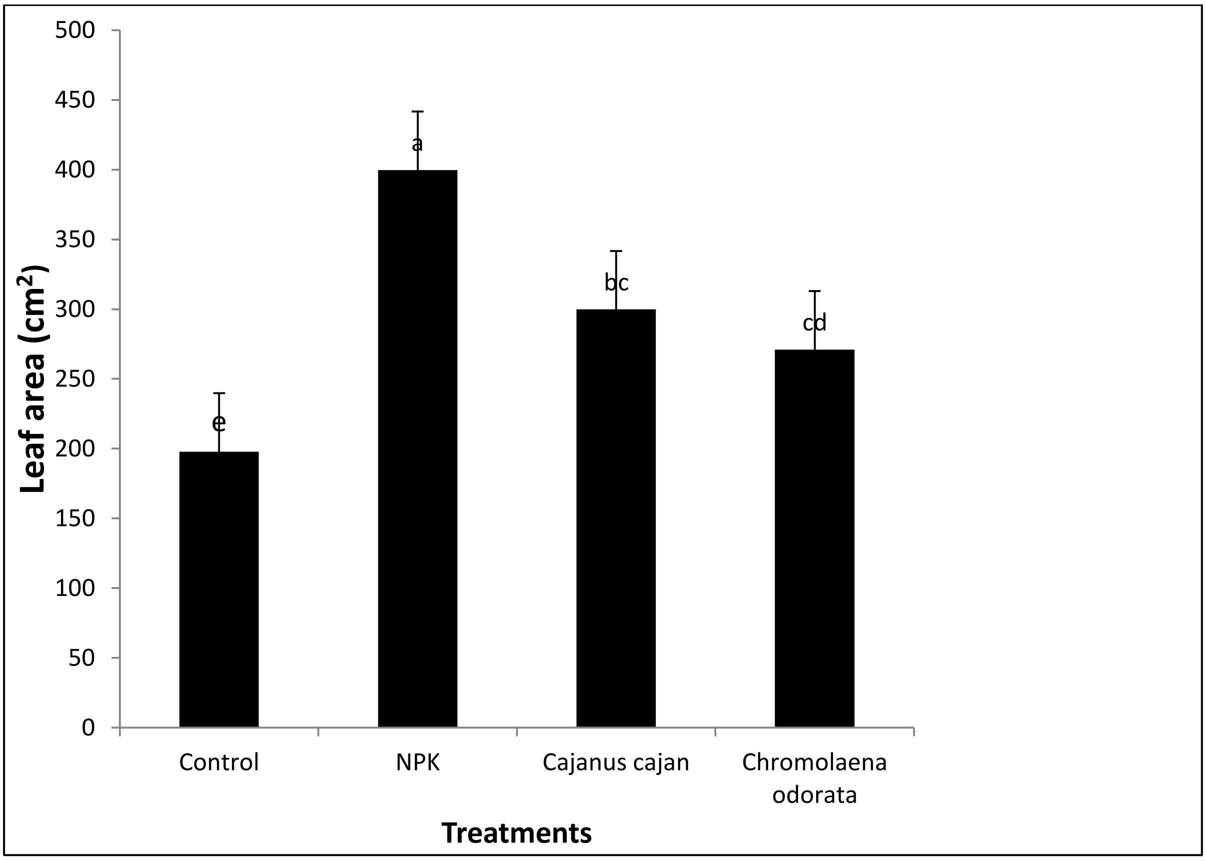

Figure 5: *The effects of mulches and NPK on leaf area (cm^2) at 8 WAP of maize in 2013*

Legend: WAP: Weeks after planting

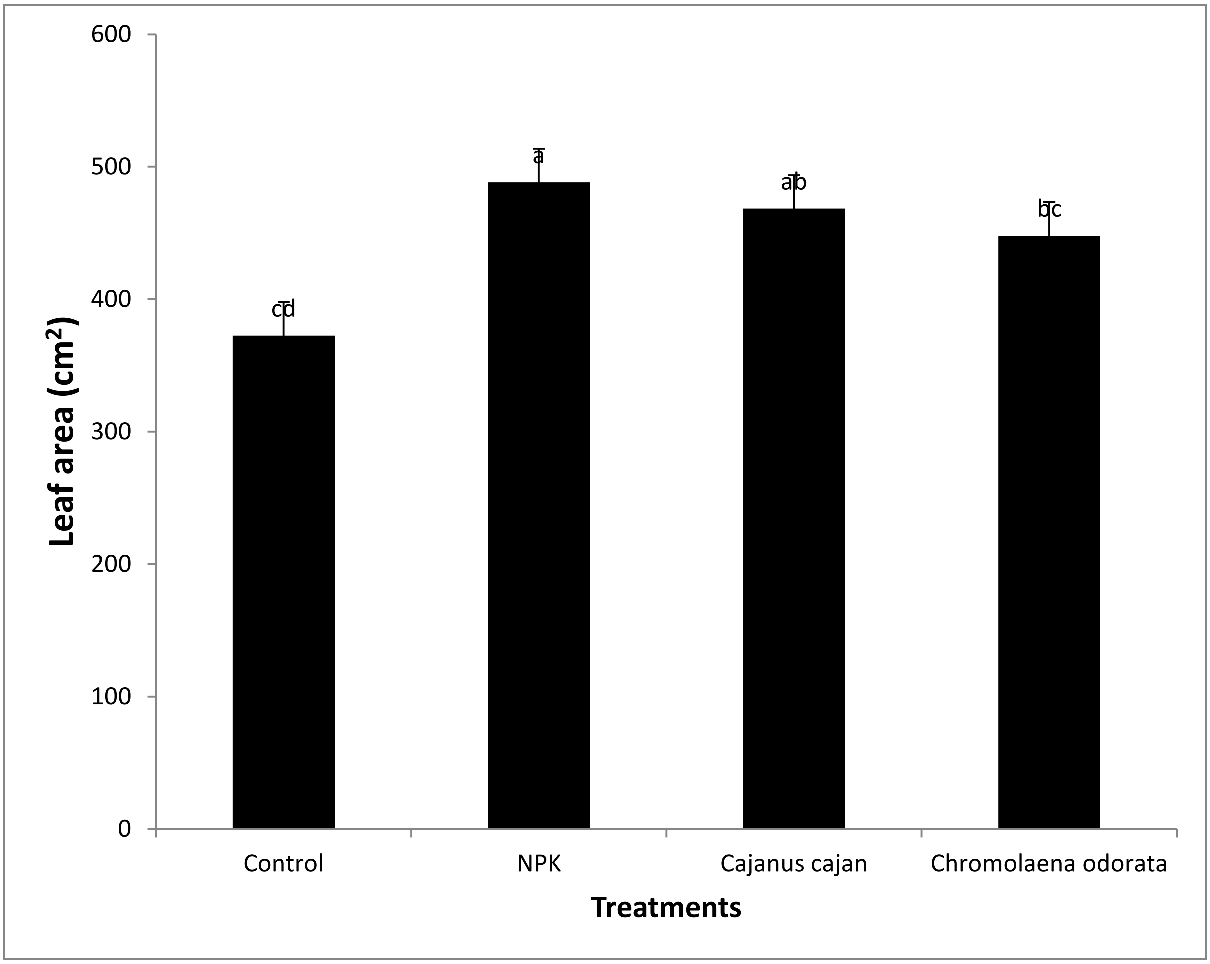

Figure 6: *The effects of mulches and NPK on leaf area (cm^2) at 8 WAP of maize in 2014*
Legend: WAP: Weeks after planting.

Table 4: Effects of mulches and NPK fertilizer on maize yield parameters at the end of 2013 cropping

Dry matter **Treatment**	**Grain yield ($t\ ha^{-1}$)**	**Biomass ($t\ ha^{-1}$)**	**Shelling Yield ($t\ ha^{-1}$)**	**Harvest percentage (%)**	**index (%)**
Control	0.98d	0.63d	3.05c	70.31ab	20.66bc
NPK (20:10:10)	2.32a	2.19a	7.55a	72.10ab	29.01ab
Cajanus cajan	1.65bc	0.93cd	4.84bc	68.59ab	19.21c
Chromolaena odorata	1.63bc	1.10cd	4.54bc	72.19ab	24.23bc

Means followed by the same letter within each column are not significantly different (P= 0.05) as indicated by Duncan's Multiple Range Test

Table 5: Effects of mulches and NPK fertilizer on maize yield parameters at the end of 2014 cropping

Dry *matter* Treatment	**Grain yield ($t\ ha^{-1}$)**	**Biomass ($t\ ha^{-1}$)**	**Shelling Yield ($t\ ha^{-1}$)**	**Harvest percentage (%)**	**index (%)**
Control	1.94d	1.23cd	4.98d	63.97c	24.65c
NPK (20:10:10)	3.18a	2.76a	9.12a	74.66a	30.26a
Cajanus cajan	2.94a	2.41a	7.58b	76.39a	31.79a
Chromolaena odorata	2.55bc	2.29ab	7.40bc	68.39bc	30.95a

Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Duncan's Multiple Range Test

Conclusion

This study has shown that the application of organic mulches such as *Cajanus cajan* and Chromolaena *odorata* has the potential of improving maize growth, biomass and yield which are comparable to inorganic fertilizers. It is pertinent to note that the organic mulches have the added advantage of improving soil quality and health which was observed in the increase in soil organic carbon and also its weed growth suppressing attribute which creates a conducive environment for maize production in the study area. It is recommended that small holder farmers should make use of *Cajanus cajan,* an easily available leguminous organic mulch applied at 5t/ha as an alternative to scarce and expensive recommended rates of NPK fertilizer or combined with reduced recommended rates of NPK fertilizer in the study area to boost maize production in their various holdings.

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